Carbonaceous Inclusions in Meteorite Chondrules as Characterized Using Confocal Raman Imaging

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Inclusions within chondrule mineral grains in the Allende CV3 meteorite have been characterized using confocal Raman spectroscopic imaging. The inclusions are isolated "islands" of material within mineral grains inside chondrules, and so may represent carbonaceous material dating to the formation of chondrules from the protoplanetary disk. These inclusions are found to predominantly contain poorly graphitized carbon, and many include (Fe, Ni) sulfides, mineral grains, metal oxide spinels, and a few instances of the phosphate whitlockite. The distribution of inclusion contents varies widely from one inclusion to the next, and reduced carbon/sulfide inclusions can be separated from metal oxide spinels by less than 10 micrometers in their parent mineral grain. By virtue of their protected location within chondrules, these materials have been relatively protected from aqueous alteration in the meteorite parent body and from terrestrial alteration. At this point their formation mechanism is uncertain and may include a range of possibilities from pre-chondrule processes up to later-stage alteration of embedded metal blebs, but in any event they appear to offer insights into chondrule formation and possibly the delivery of unaltered organic species to the early Earth and elsewhere.